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13. ABSTRACT (Maximum 200 words)

This report results from a contract tasking R&D Bureau of the Institute for Low Temperature Physics and Engineering as follows: The contractor will investigate techniques for accelerated testing of cryocooler technology. During this phase of the effort, the contractor will perform a detailed design of the equipment needed to conduct accelerated testing. Details are contained in the proposal statement of work designated as Tasks II and IIA.

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**SPECIAL RESEARCH AND DEVELOPMENT BUREAU
IN CRYOGENIC TECHNOLOGIES OF B. VERKIN INSTITUTE
FOR LOW TEMPERATURE PHYSICS AND ENGINEERING
OF NATIONAL ACADEMY OF SCIENCES OF UKRAINE**

METHODOLOGY OF ACCELERATED LIFE- TIME TESTS FOR STIRLING-TYPE "BAE-Co"-MADE CRYOCOOLERS AGAINST DISPLACER- BLOCKAGE BY CRYO- POLLUTANT DEPOSITS STAND MOCK-UP EXPERIMENTS

(Interim report-Deliverable 3)

**Additional Agreement
of Nov.11, 99 to #7 Contract**

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January, 2000

Contents

INTRODUCTION

Accordingly with Additional Agreement of Nov.1, 1999 to #7 Contract with “Orbita Ltd” Co.,the SR&DB- CT-ILTPH&E- NASU executes its work activities in creation of technical documentation to stand equipment and facilities for accelerated tests of compressors in long- life Stirling- type linear drive cryocoolers (manufactured by “Bae Co.”)

The reported period covers work activities done in four issues:

1. A development of technical documentation to piston gap - sealing wear check stand.
2. A development of technical documentation to test stand and methodology of accelerated life-time tests for Stirling-type cryocoolers against blockage of cryocooler displacer unit by cryogenic deposits.
3. A development of technical documentation to stand and to mock-up test for compressor body gas tightness at accelerated thermo- cycling
4. A development of technical documentation to compressor linear drive high-frequency stand and to mock-up test of the flexible springs pilot samples at different frequencies.

In compliance with Issue 1, a first edition of principal pneumo- hydraulic scheme of the test stand has been forwarded to the Customer Current report represents 2nd revised version of above scheme (see Fig.2.1). Compressor gap- sealing wear check stand is an individual component of the Helium Complex Stand (HCS) facility. Another constituent component of HCS is a stand for accelerated tests to blockage of the displacer by condensed cryogenic deposits. Such a designer’s concept has enabled us to sufficiently, almost as twice, reduce metal consumption and cost of the HCS as a whole, and to arrange for more compact layout of HCS equipment and facilities, thus saving a portion of HCS premise room.

In compliance with issue 2, there has been developed a methodology for accelerated tests of the displacer blockage by condensed cryogenic deposit as represented in Chapter 1. Besides this, there has been carried out a detailed design development of connections to interface the HCS facilities with standard test equipment to be supplied by US-party. Chapter 2 represents a list of requirements to said test equipment. Here in this chapter are also represented detailed connection schemes to interface the HCS with standard US-made test equipment,including:

- a standard frequency test cryocooler;
- a high- frequency test cryocooler;
- two thermal chambers to stabilize temperature of cryocoolers
- cryocooler interface armature;
- two vacuum outpumping systems;
- facilities for filling the HCS with liquid nitrogen, admixture gases and distilled water;
- a mass spectrometer for gasouus media monitoring, and
- pressurized gas bottles.

These documental materials are assumed to enable the US- party to be prepared, in advance, to discussion of technical aspects during pre-planned visit of SR&DB experts to the AFRL in early February 2000.

Following the Issue 3 , there has been accomplished a development of the stand principal schemes. In the course of development, there has appeared a necessity to experimentally specify temperature regimes of thermocycling with purpose of selection for optimal cryoagent and method of cooling hereof. For this reason, there has been - engineered a mock-up stand, and tested under different temperature regimes a full- scale cryocooler body mock-up. Based on test results, there has been determined cooling temperature of $-70^{o}C$. Chapter 3.1 represents test results and resume hereto.

Chapter 3.2 represents technical requirements to three cooling system versions, with application of:

- a standard cooling machine to be supplied by US-party;
- liquid nitrogen;
- solidified carbonic acid gas.

A final choice of cooling system requires a discussion with US-party at the would-be meeting in AFRL.

In compliance with issue 4, there has been tested a compressor piston suspension mock-up prototype with employment of a mock- up stand provided for these reasons in previous times. As test results, there has been obtained a curve characteristic of the drive power dependence on frequency within 30 до 1100 Hz range.

It was found that said curve possesses a series of specifically notable resonance peaks of low power consumption rate, which is assumed to be a result of mechanical resonance that occurs within springs as a whole and within separate structural parts of springs. In the course of high- frequency test of compressor, there appears a need to determine said frequencies and, hence, to rearrange the test procedures to a reduced or increased frequency. With this purpose, the high- frequency compressor test stand will be provided with appropriate facilities. Chapter 3.3. covers detailed results data hereof.

Chapter 4 of the Report contains requirements to complete- set equipment and facilities of US make for compressor body accelerated thermocycling test stand.

Chapter 5 of the Report includes similar requirements to compressor linear drive high-frequency fatigue test stand.

1. ACCELERATED TESTS METHODOLOGY FOR STIRLING-TYPE CRYOCOOLERS AGAINST CRYO-DEPOSIT FAILURES

Selected list of abbreviations:

A5 = helium mixture container unit
A6 = pollutant cryodeposit collector unit
A7 = vapor generator unit
CAU = cryodeposit accumulation unit, the «CAU-trap»
CH1 = cryocooler
CS1 = cryocooler
GC1... GC8 = eight gas bottles
HCS = helium complex stand facility.
LN = liquid nitrogen
MS = mass spectrometer
RS1 = vapor generator vessel
RS2 & RS3 = receiver vessels
TC1 = thermo-controlling chamber
UN2 = pipe ends
VH1 = inlet lock valve
VH2 = by-pass lock valve
VH3 = outlet lock valve
VF2 = adjustment valve

The accelerated tests for stability of Stirling-type cryocoolers against blockage of cryogenic equipment by cryo-deposits is implemented by means of helium complex stand (HCS) facility.

Principal pneumo-hydraulic scheme of the stand is represented at Fig 2.1.

These tests are available for both:

CS1-type cryocooler to operate at standard frequency, and

CH1-type cryocooler having undergone a cycle of high- frequency tests.

The HCS equipment and facilities for cryo-blockage accelerated tests provide solution of the following tasks:

- long-term performance of the CS1 cryocooler at nominal frequency at maximum admittable environmental temperature;
- change in composition and in amount of admixtures (being resultant outgassing products of system-structure materials) in working fluid of the CS1 cryocooler, after its long-term non-stop performance at nominal frequency and at maximum admittable environmental temperature within 3 to 6 months interval;
- preparation and filling of CS1 and CH1 cryocoolers with water vapor of pre-determined parameters;
- preparation and filling of CS1 and CH1 cryocoolers with working fluid containing pre-determined amount of (CO_2, CO, N_2, CH_4 etc) «pollutant» gas admixtures capable of forming cryodeposit blocks inside the displacer unit structure;
- monitoring of admixture amounts and composition in working fluid of CS1 and CH1 cryocoolers at different regimes;
- implementing test procedures for CS1 and CH1 cryocoolers operating with «dirty» working fluid to check out for compliance with parameters hereof (like cryostatting temperature, consumed power, vibration level etc) to Certification-guaranteed data.

For performance test of the CS1 cryocooler, there will be employed US-made standard facilities.

INTEGRATED TEST METHODOLOGY

1. Forecasting an Amount of Cryodeposits inside Cryocoolers in 10 years operation

Forecast procedures to predict an amount of cryodeposit «dirt» to accumulate inside the cryocoolers by the end of their expected performance life should be carried out over 2 stages. The first stage, one year long, includes 4 measurement procedures for amount of cryogenic dirt accumulated, in every three months of operation within a cryocooler- displacer's cold zone, due to outgassing by cryocooler-component materials. At second stage, obtained results will be analyzed, and following a special methodology, there should be carried out computations for cryogenic «dirt» amount that would accumulate inside the cryocoolers by the end of their 10-year service life.

Changes in composition and in amount of admixtures in working fluid of the cryocooler that operated at nominal frequency should be measured in the following manner:

1.1. The cryocooler should be stopped in order to re-warm its displacer unit up to room temperature.

1.2. The cryocooler should be warmed up to 85^{o}C ultimately permitted so-called «survival» temperature being monitored by sensor of thermo-controlling chamber TC1 (of A3 unit) and located near to the cryocooler mounting spot.

1.3. There is provided an extraction of helium samples from cryocooler, via heated thermo-insulated piping, with purpose of admixture-amount control by means of mass-spectrometer.

1.4. Further, helium is released from the cryocooler and passes through «trap», i.e., nitrogen cryodeposit accumulation unit (CAU) inside A6 unit out into environment at 0.11 Mpa residual pressure.
In the course of helium release and prior to finish, some portion of post-trap helium is sampled with purpose of monitoring residual amount of admixtures by means of mass-spectrometer.

1.5. Next, the cryocooler should be filled again with purified helium up to 1.4 MPa nominal filling pressure, and retained under +85^{o}C survival temperature for minimum 1 to 2 hours (the time term should be specified with methodology optimization with application of cryocooler simulation unit).

1.6. The cryocooler shall be kept until its temperature goes down to +40^{o}C (owing to temperature decrease around cryocooler mounting spots inside the thermo-control chamber down to 0-20^{o}C).

1.7. The cryocooler shall be actuated on for 10 to 15 minutes in order to make the helium mass agitated, and then be re-warmed up to +85^{o}C again.

1.8. There is provided an extraction of helium samples from cryocooler, via heated thermo-insulated piping, with purpose of admixture-amount monitoring by means of mass-spectrometer.

1.9. Helium is released, for the second time, from the cryocooler through the same nitrogen cryo- adsorption «trap» (of A6 unit) into environment up to 0.11 MPa residual pressure.

In the course of helium release and prior to finish, some portion of post- trap helium is sampled with purpose of monitoring residual amount of admixtures by means of mass-spectrometer.

1.10. The cryocooler should be filled again with purified helium up to 1.4 MPa filling pressure, and be retained under maximum admittable temperature within minimum 1 to 2 hours

1.11. The cryocooler temperature shall be let down to +40^{o}C owing to temperature decrease for its mounting spots inside the thermo-control chamber down to 0-20^{o}C.

1.12. The cryocooler shall be switched on again for 10 to 15 minutes to agitate helium.

1.13. The cryocooler shall be re-warmed up to +85^{o}C.

1.14. An extraction of helium samples from cryocooler, via heated thermo-insulated piping, is provided to control an amount of admixtures by means of mass-spectrometer.
If there occurs a notable appearance of admixture content in a given sample (i.e., up to 1-5% over the same in initially sampled helium, per para. 1.3) for any de-sublimating component, the procedures per paras. 1.9 ... 1.14 should be reproduced again
If content of admixtures is negligible, tests should go further on per. para 1.15 and so forth.

1.15. Helium should be released from the cryocooler for the third time, through the same cryo-adsorption trap, out into environment up to 0.11 MPa residual pressure.
And again, another helium sample (prior to its release end) is routinely controlled by means of mass spectrometer.

1.16. The cryogenic CAU-trap should be shut off the cryocooler system (by means of lock valves). Now, the cryocooler should be used in tests for scavenging the compressor piston-bore gap sealing.

1.17. Helium will be outpumped from the cold trap by means of membrane-type fore-vacuum pump unit-1 up to maximum 1 Pa residual pressure.

1.18. The **VH11** valve of CAU- trap in A6 unit should be shut up, thus separating cavities of regenerating heat exchanger HR1, in order to freeze out the water from cryo-adsorber AC1.

1.19. The interlocked CAU- trap should be warmed up to 100 ... 150^{o}C temperature.

1.20. Temperature and pressure inside the CAU-trap cavities of determined volume should be measured.

1.21. Contents of gases and vapors inside both cavities of the CAU-trap should be analyzed by means of mass spectrometer, along with subsequent definition of percentage of admixture-contents capable of forming cryodeposit blocks at cryocooler operation temperatures.

1.22. Absolute value of cryodeposit amount accumulated within 3 months of the cryocooler performance, inside its working fluid, should be computed.

2. Filling the CS1 or CH1 Cryocoolers with a Pre- Determined Amount of Water Vapors

Filling the cryocoolers with a pre- determined water vapors amount should be done my means of vapor generator, the A7 unit.

2.1. The cryocooler should be vacuumized (usually by means of a membrane- type fore-vacuum pump alone or, when necessary, together with a turbo- molecular pump of outpumpung unit-1), and then cooled down to -40...-20^{o}C by means of a relevant thermo- controlling chamber.

2.2. At + 50 ^{o}C temperature,there should be arranged an equilibrium state inside the RS1 vapor generator vessel (with boiling degassed double- stillage distilled water), by means of HC1 thermal chamber of A7 unit, and RS1 vapor generator.

2.3. Saturated water vapor from the A7 - RS1 vapor generator unit should be conveyed, under equilibrium 92.5 mm Hg pressure and via VF1 adjustment valve, into preliminarily outpumped receivers RS2 and RS3 possessing somewhat higher temperature, like +65...+70^{o}C. Further on, said receivers, RS2 and RS3, will be shut off the RS1 vessel by means of valves VF1 and VH1.

2.4. Temperature of RS2 and RS3 vessels, of connecting piping hereof and gas- lock armature is maintained as constant at +65...+70^{o}C temperature level by means of A7-HC1 thermo-chambers and helium complex stand facilities, along with auxiliary heaters and temperature sensors upon locking valves of cryocoolers.
NOTE: these facilities are not shown in Fig.2.1

2.5. There is arranged an optimized volume of receivers, (of combination of RS2 + RS3, or RS2 alone), along with computation for finite pressure of overheated steam herein, in dependence on amount of water vapor required for filling a cryocooler.

2.6. Overheated steam is forwarded from vapor generator to a relevant «cold» cryocooler to be frozen out.

2.7. Amount of water vapor filled into a cryocooler should be monitored through pressure drop across vapor generator receivers RS2 and RS3.

3. Preparation and Filling the CS1 or CH1Cryocoolers with Working Fluid Containing a Pre- Determined Amount of Gaseous Admixture Pollutants

3.1. A computed «dirty» working fluid of a cryocooler should be prepared in a preliminarily cleaned (by means of vacuumizing with subsequent overheat) filling vessel RS1 of helium mixture container unit A5 being outpumped down to maximum pressure 1 Pa by means of membrane- type fore- vacuum pump of outpumping unit 1.

3.2. In order to provide required computed partial pressure values, the admixture pollutant gases should be fed, one by one and at definite 20-35 ^{o}C temperature, from any of eight bottles GC1... GC8 into a filling vessel, through adustment in-leaker*** valves and a heat exchanger.
Pressure inside the filling vessel should be controlled by meams of vacuum and vacuum-presser gauge sensors.
***NOTE:** the «in-leaker» means a piezo-sensitive device that monitors microscopic dosages of in- leaking gases for purpose of investigation

3.3. The filling vessel should be filled with helium from helium bottles GC1 and GC2 belonging the stand facilities, whereby helium is purified inside the CAU- trap of A1 unit up to computed pressure about 2.0 mPa.

3.4. Pollutant admixture content inside the prepared working fluid of cryocoolers should be additionally monitored by means of mass spectrometer.

3.5. The «dirty» helium is fed from filling vessel (through VF2 adjustment valve) simultaneously into both compressor and displacer cavities of the cryocooler, until required filling pressure sets in.

3.6. The cryocooler should be pressurized by means of its own gas-locking armature.

4. Testing of the Cryocoolers Operating with «Dirty» Working Fluid

Testing of the cryocoolers that operate with «dirty» working fluid should be implemented in compliance with standard methodology based on a «performance test» with application of standard USA test equipment and facilities.

Check out for compliance of major cryocoolers characteristics (like cooling temperature, consumed power, vibration level etc) to Certification-guaranteed data should be carried out.

2. REQUIREMENTS TO USA- MADE EQUIPMENT FOR HELIUM COMPLEX STAND

Fig. 2.1 shows mating points to interface the USA–made equipment with helium complex stand (HCS) facilities.

The HCS equipment preliminary layout-scheme (to be completed with American and Ukrainian components) is shown in Fig.2.2.

Fig.2. 1. Principle pneumo-hydraulic schema of the complex helium stand

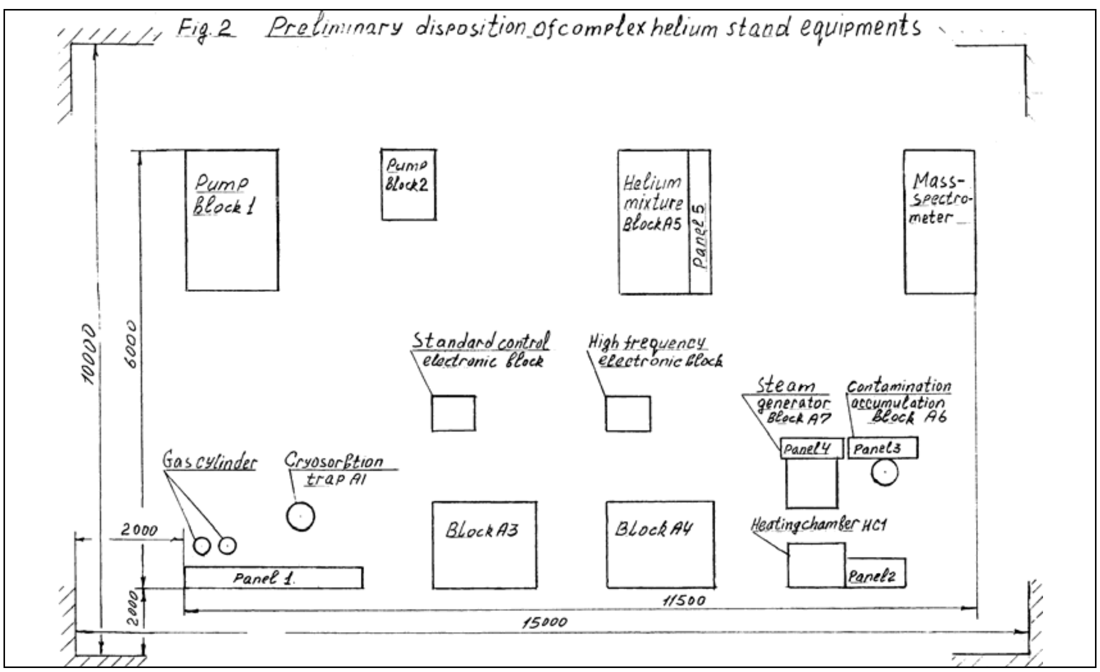

Fig.2. 2. Preliminary disposition of complex helium stand equipments

1. CS1 and CH1- type cryocoolers

1. 1. Optimization of the CS1 and CH1- type cryocoolers structural design

1.1.1. For the purpose of interfacing with HCS facilities , any of the CS1 è CH1- type cryocoolers should be provided with three lock valves:

a) an inlet valve VH1 in a pipeline intended for helium supply into compressor drive- case cavity:

b) an outlet valve VH3 in a pipeline circuited to connecting tube between displacer and compressor units;

c) a by- pass valve VH2.

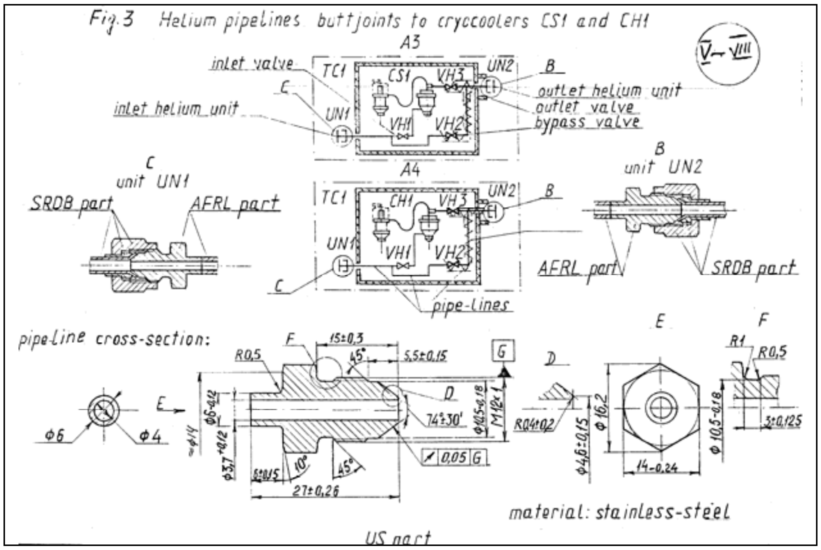

Fig.2. 3. Helium pipelines buttjoints to cryocoolers CS1 and CH1

Fig 2.3 shows schemes of lock valves VH1 - VH3 connection to cryocoolers, along with recommended design of connection armature to interface said cryocoolers with HCS.

1.1.2. General Requirements to Lock Valves

a) valve conditional I.D. : 4 mm; operational pressure: minimum 2.5 Pa;

b) valves' pressure- tightness across gate and body : miniumum $1*10^{-9}$ m^3 Pa/s;

c) maximum outgassing rate of valve structure into inner cavity: $1*10^{-9}$ m^3 Pa/s;

d) all the valves should be capable of operation under -40 to +85^{o}C temperature interval.

1.1.3. The VH2 and VH3 lock valves of every cooler, as well as connecting pipes therebetween and pipes between ends UN2 (see Fig.2.2) should be furnished with protective heat-insulation, self- sustainable electric heaters and temperature sensors with purpose of temperature maintenance and control within + 40 to +85 ^{o}C temperature interval.

Thermal resistance of the total heat- insulation pack should make up minimum 10K/W.

Integral power of electric heaters should amount to minimum 100 W.

Temperature sensors should be mounted on every VH2 and VH3 lock valve heated, and on every end connection of pipes therebetween.

NOTE: It is assumed that design of mating joints for electric heaters and temperature sensors with HCS control unit hardware should be specified in subsequent order.

1.1.4. The CS1 and CH1 cryocoolers should be located, together with piping armature, inside the thermo- controlling chambers TC1 of A3 and A4 units, correspondingly. Fig.2. 3 shows location of connecting UN1 and UN2 pipeline outlets, along with location of hand-control knobs of VH2 and VH3 lock valves upon exterior walls of TC1 chambers.

1.1.5. The mounting spots of CS1 and CH1 cryocoolers should be furnished with temperature sensors of - 40 to +120^{o}C temperature range.

1.2. Supply Status of CS1 & SH1 Cryocoolers for Accelerated Tests

1.2.1. The CS1 and SH1 cryocoolers should be equipped in compliance with para. 1.1 and be filled with working fluid up to nominal pressure.

1.2.2 The supply complete set for above-said coolers should include:

- operational documentation;
- electronic hardware standard units for conventional performance of said cryocoolers;
- an equipment and facilities for testing said cryocoolers (such as thermal load simulation cooling temperature measurement, consumed power measurement, displacer cold-end vibration measurement etc.);
- means of vacuum maintenance and control inside the displacer cryostat at long-term operation anf testing of said cryocoolers.

2. Thermo- Control Chambers TC1 of A3 and A4 Units

2.1. Chamber Structure Design

2.1.1.The following hardware should be lodged inside thermo- control chambers TC1 within A3 and A4 units:

- CS1 and CH1 cryocoolers with their corresponding:
- lock valves VH1-VH3.

The control knobs of lock valves VH1-VH3 should be situated upon thermo-control chamber walls facing helium stand front panel, see Figs. 2.2 and 2.4.

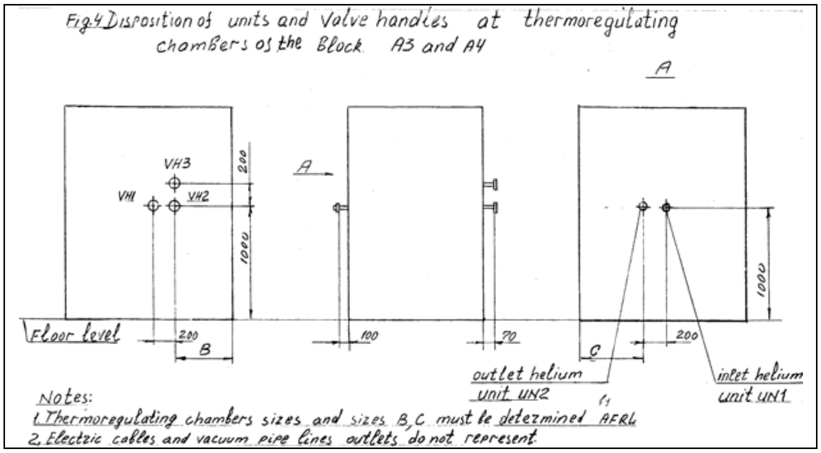

Fig. 2.4. Disposition of units and valves at thermoregulating chambers

2.1.2. The mounting spots for said cryocoolers should correspond to structural design hereof.
2.1.3. Lock valves VH1-VH3 should be mounted upon heavy-duty parts of the system, being provided with thermo-insulation spacers possessing minimum 5 K/W thermal resistance each.
2.1.4. The thermo-control chambers TC1 of A3 and A4 units should be provided with inlet/ outlet ports for electric lines and pressure pipes as is following:

- a connecting cable between a cryocooler and a standard US-made electronic unit;
- a connecting cable between a cryocooler and a standard US-made electronic facility for testing said cryocoolers;
- a connecting cable between CH1 cryocooler compressor and high-frequency electronic unit (for only a TC1 chamber of A4 unit);
- transmission cables from cryocooler temperature sensors,
- pipes of valves and pipelines, and
- electric heaters, per para 1.1.3 (USA- made hardware), to helium- stand control panel;
- connecting pipes for inlet/ outlet of helium and working fluid to/from said cryocooler;
- a pipeline for displacer cryostat vacuumization (USA- made hardware).

2.1.5. Layout of connecting pipe UN1 è UN2 outlets (upon outer walls of TC1 chambers) is shown in Fig.2.3.
2.1.6. It is assumed that design and inlet/ outlet terminals of electric cables that connect:

- CH1 cryocooler compressor;
- high- frequency electronic unit;
- cryocooler temperature sensors,
- should be specified in consequent work stages.

2.1.7. The dimension and mount/ installation drawings of thermo-control chambers, along with drawings of corresponding auxiliary equipment and facilities with operational documentation hereof, should be coordinated with SR&DB-ILTPh&E in order to specify the HCS hardware configuration, and to develop programs and methods of accelerated tests.

2.2. Requirements to Thermo-Control Chamber Performance Regimes under Accelerated Test Conditions

2.2.1. The TC1 chambers of A3 and A4 units should, correspondingly, maintain pre-determined values of temperature for CS1 and CH1 cryocoolers under following operational and regime conditions:

- CS1 cryocooler performance at standard frequency;
- high- frequency tests of CH1 cryocooler;
- testing said cryocoolers to prove a normal operation ability hereof;
- release of working fluid from the cryocooler;
- release of working fluid from the CS1 cryocooler through a cryogenic CAU-trap;
- scavenging of compressor- clearance sealing;
- filling the cryocooler with pure helium;
- filling the cryocooler with gas mixture.

2.2.2. Operational temperature characteristics of the cryocoolers at different operational and test regimes are shown in Table 2.1:

Table 2.1

##	Description of a regime	temperature interval ^{o}C	single regime (cycle) duration
1	CS1 cryocooler operation at standard frequency	-20 ... -40	1-2years
2	High- frequency tests of CH1 cryocooler	-20 ... -40	1-2years
3	Cryocooler performance testing	-20 ... -40	up to 24 hrs
4	Working fluid release from the cryocooler	-20 ... -35	up to 1 hr
5	Working fluid release from the CS1 cryocooler through cryogenic trap	-70... -85	hrs
6	Scavenging the compressor piston-bore clearance sealing	-20 ... -35	to 4 hrs
7	Filling the cryocooler with pure helium	-20 ... – 35	up to 1 hr
8	Filling the cryocooler with gas mixtures	-40 ... +35	1 to 5 days

2.2.3. Thermal load on thermo-control chamber A4 - TC1 amounts to maximum 400 W, not including environmental heat in- flows, at high-frequency test of the CH1 cryocooler.

2.2.4. Thermal load from cryocoolers on chambers at other test regimes is preliminary assumed as maximum 200 W, not including heat exchange with environment, and is subject to further study.

2.3. Electric Power Supply, Monitoring and Control of Thermo-Controlling Chambers

Electric power supply, monitoring and control of thermo-controlling chambers are provided autonomously and in accordance with relevant operational documentation.

3. Vacuum- Outpumping Unit 1 of the HCS

3.1.Recommended list of Vacuum- Outpumping Unit 1 facilities.

The vacuum-outpumping unit 1 facilities should include:
- a membrane-type forevacuum pump;

- a turbo-molecular (cryo-sorption) vacuum pump;
- a nitrogen CAU- trap;
- vacuum locking armature to control the unit and to mate it with HCS stand;
- vacuum measurement means;
- auxiliary equipment and facilities;
- helium leakage- detector.

3.2.Requirements to Vacuum- Unit -1 Design.

3.2.1. Figs.2.2 and 2.5 show preliminarily determined area for disposition of vacuum unit-1, and recommended devices for interfacing hereof to #1 panel of the HCS stand, respectively.

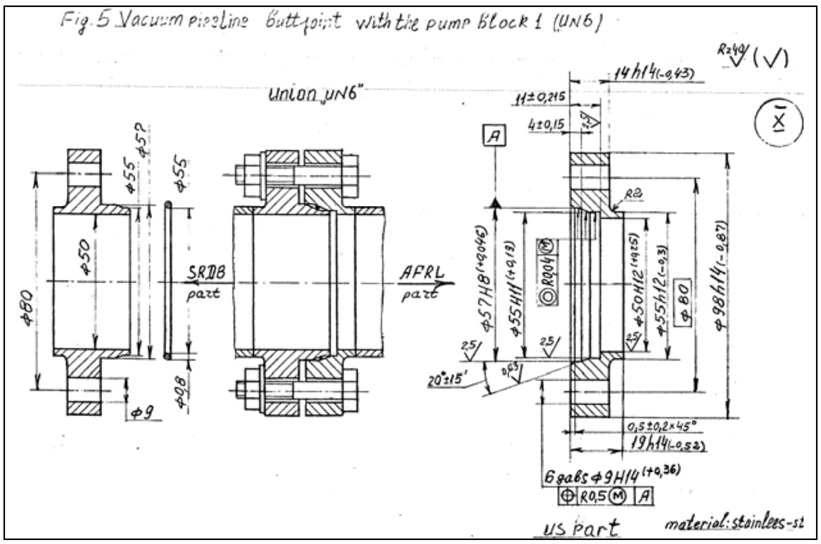

Fig.2.5.Vacuum pipeline buttjoint with the pump block 1 (UN6 of helium stand)

3.2.2. Inlet portion of the vacuum unit-1 should be provided with a facility to connect a (US-made) helium leakage detector possessing 1*10^{-11} ì^{3}Pà/s sensitivity at fan- method operation.

3.2.3. The dimension and mount/ installation drawings of vacuum unit-1, along with drawings of corresponding auxiliary equipment and facilities with operational documentation hereof, should be coordinated with SR&DB-ILTPh&E in order to specify the HCS hardware configuration, and to develop programs and methods of accelerated tests.

3.3.Requirements to Vacuum- Unit -1 Technical Characteristics:

3.3.1. The vacuum unit- 1 should provide a vacuumization of the HCS equipment and facilities at the following operations and regimes:
- preparation of the HCS to tests;
- preparation of gas samples for mass spectrometer;
- regeneration of adsorbent agent in A1 unit CAU-trap;
- regeneration of adsorbent agent in A6 unit CAU-trap;

- helium release from CS1 and CH1 cryocoolers (mounted onto the HCS stand) through A6 pollutant- cryodeposit collector unit trap;
- - preparation of helium mixture container unit A5 to performance;
- preparation of the CH1 cryocooler to high- frequency tests;
- preparation of the CH1 cryocooler to fill it with pure helium for testing;
- preparation of the CS1 cryocooler to fill it with polluted «dirty» working fluid.

3.3.2. The media being outpumped is composed of helium and admixture gases (like hydrogen, water vapors, CO2, CO, oxygen, nitrogen, argon, light hydrocarbons).

3.3.3. Table 3.2 represents required outpumping rates and ultimate vacuum values at inlet to vacuum unit-1 while implementing procedures per para. 3.3.1:

3.3.4. The back- flow of oil vapors into cavities being outpumped is not admittable.

Table 2.2

##	Task, regime	Outpumping means	Requirements to vacuumization	
			Ultimate vacuum,Pa	**outpumping rate, l/s**
1	Preparation of the HCS to tests	vacuum unit-1: fore-vacuum pump; high- vacuum pump	0.5 $1*10^{-4}$ maximum	minimum 5 mimimum 100
2	Preparation of samples for mass spectrometer	vacuum unit-1: fore- vacuum pump; high- vacuum pump	0.5 $1*10^{-4}$ maximum	minimum 5 mimimum 100
3	Regeneration of adsorbent agent in A1 unit CAU-trap;	vacuum unit-1: fore- vacuum pump;	maximum 0.5	mimimum 5
4	Regeneration of adsorbent agent in A6 unit CAU-trap;	vacuum unit-1: fore- vacuum pump;	maximum 0.5	mimimum 5
5	Relium release from CS1 and CH1 cryocoolers (mounted onto the HCS stand) through A6 pollutant- cryodeposit collector unit trap;	vacuum unit-1: fore- vacuum pump;	maximum 0.5	mimimum 5
6	Rreparation of helium mixture container unit A5 to performance;	vacuum unit-1: fore- vacuum pump;	maximum 0.5 $1*10^{-4}$	mimimum 5 mimimum 100
7	Preparation of the CH1cryocooler to high- frequency tests;	vacuum unit-1:	100 – 1000	minimum 5
8	Preparation of the CH1 cryocooler to fill it with pure helium for testing;	vacuum unit-1: fore- vacuum pump;	maximum 0.5 $1*10^{-4}$	mimimum 5 mimimum 100

9	Preparation of the CS1 cryocooler to fill it with polluted «dirty» working fluid	vacuum unit-1: fore- vacuum pump;	maximum 0.5	minimum 5
10	Preparation of A7 vapor generator unit to performance	vacuum unit-2: fore- vacuum pump;	maximum 0.5	minimum 5
11	Outpumping of RS1 vessel of A7 unit in preparation of saturated steam	vacuum unit-2: fore- vacuum pump;	maximum 0.5	minimum 5
12	Outpumping of vacuumized space of A1 and A6 CAU- traps	vacuum unit-2: fore- vacuum pump	maximum 0.5	minimum 5

3.3. Electric Power Supply, Monitoring and Control of Vacuum Outpumping Unit-1

Electric power supply, monitoring and control of vacuum outpumping unit-1 are provided autonomously and in accordance with relevant operational documentation.

4. Vapor Generator Vacuum Outpumping Unit-2

4.1. Recommended list of Vacuum- Outpumping Unit- 2 facilities.

The vacuum- outpumping unit-2 facilities should include:
- a membrane- type forevacuum pump;
- vacuum locking armature to control the unit-2 and to mate it with HCS;
- vacuum measurement means;
- auxiliary equipment and facilities.

4.2.The requirements to design of vacuum outpumping unit-2.

4.2.1. Figs.2.2 and 2.6 show preliminarily determined area for disposition of vacuum unit-2, and recommended devices for interfacing hereof to A1, A6 and A7 units.

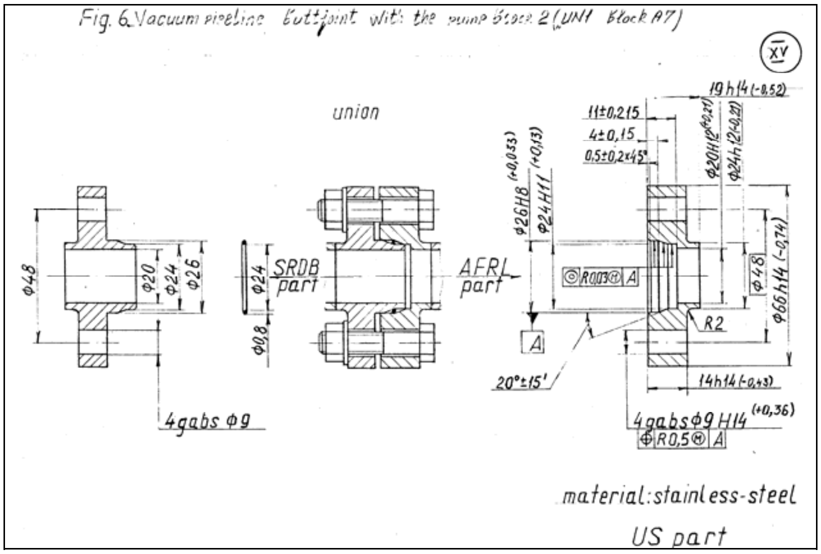

Fig.2.6. Vacuum pipeline buttjoint with the pump block 2 (UN1 bock A7)

4.2.2. The dimension and mount/ installation drawings of vacuum unit-2, along with drawings of corresponding auxiliary equipment and facilities with operational documentation hereof, should be coordinated with SR&DB-ILTPh&E in order to specify the HCS hardware configuration, and to develop programs and methods of accelerated tests.

4.3. Requirements to Vacuum- Unit -2 Technical Characteristics:

4.3.1. The vacuum unit- 2 should provide a vacuumization of the HCS equipment and facilities at the following operations and regimes:
- preparation of the A7 vapor generator unit to tests;
- outpumping of A7- RS1 vessel in preparation of saturated steam;
- outpumping of vacuumized space inside A1 and A7 CAU traps.

4.3.2. The media being outpumped are water vapors, atmospheric air, cryogenic trap- deposited outgassing pollutants.
4.3.3. Table 2.2 (see previous part) represents required outpumping rates and ultimate vacuum values at inlet to vacuum unit-2 while implementing procedures per para. 4.3.1:
4.3.4. The back- flow of oil vapors into cavities being outpumped is not admittable.

4.4. Electric Power Supply, Monitoring and Control of Vacuum Outpumping Unit-2

Electric power supply, monitoring and control of vacuum outpumping unit-2 are provided autonomously and in accordance with relevant operational documentation.

5. Helium Bottles

5.1. Requirements to Helium Bottles

5.1.1. Fig. 2.7 represents preliminarily determined overall dimensions of helium bottles and mating hardware for connecting thereof to the HCS facilities

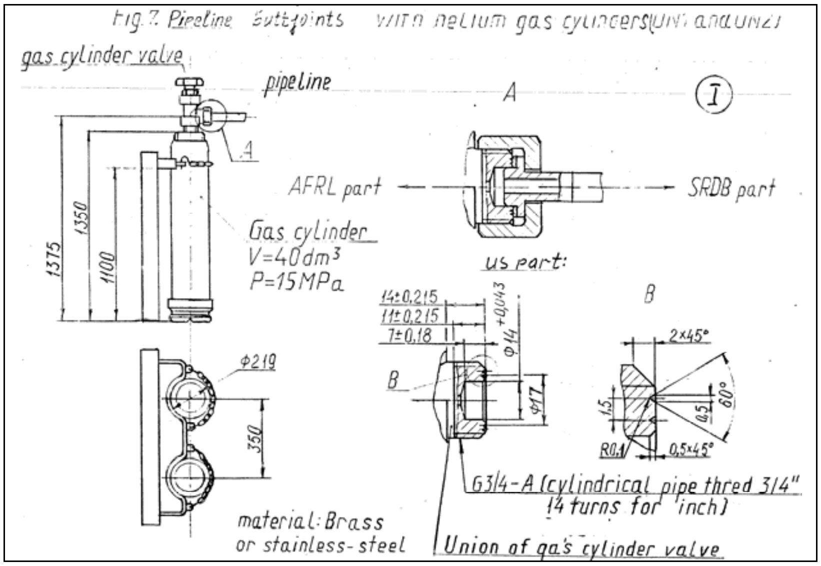

Fig.2.7. Pipeline buttjoints with helium gas cylinders (UN1 and UN2 of helium stand)

5.1.2. Every helium bottles should be furnished with standard lock valve.
5.1.3. Minimum capacity of helium bottles should make up 40 liter. Nominal helium-filling pressure makes up 15⌖0.1 MPa at room temperature.

5.2. Requirements to Helium Quality

Amount of impurities/ admixtures in helium supplied to HCS facilities (from helium bottles) should not exceed values presented by Table 2.3:

Table 2.3

#	**Index**	**volume percentage**
1	minimum voluminous proportion of helium	99.8
2	maximum voluminous proportion of hydrogen	0.06
3	maximum voluminous proportion of nitrogen	0.12
4	maximum voluminous proportion of oxygen	0.005
5	maximum voluminous proportion of argon	0.002
6	maximum voluminous proportion of ÑÎ2+ÑÎ	0.005
7	maximum voluminous proportion of hydrocarbons	0.004
8	maximum voluminous proportion of water vapors	0.004

5.3. Requirements to Helium Amount

An implementation of all accelerated tests procedures for CS1 and CH1 cryocoolers, there may be demanded maximum 90 m^3 (or up to 15 bottles) of helium.

6. Mass Spectrometer

6.1. Requirements to Mass Spectrometer Structural Design

6.1.1. Figs.2.2 and 2.8. show preliminarily determined zone for disposition of mass spectrometer and auxiliary devices in configuration of HCS, along with structural design of relevant UN5 facility for mass spectrometer mating to HCS thermal chamber HC1.

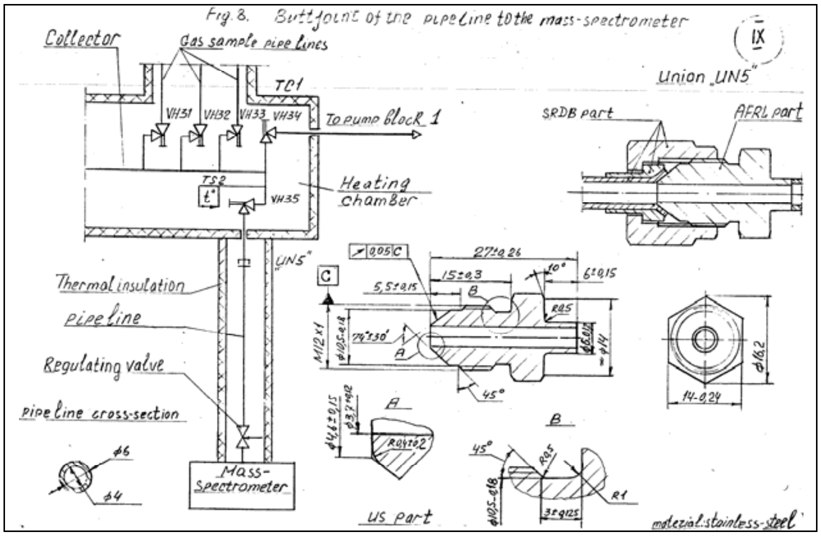

Fig.2.8. Buttjoint of the pipeline to the mass-spectrometer

6.1.2. The mass spectrometer structure should include an adjustment in-leaker valve (***see paragraph 1.3.2) ; an intermediary vacuum vessel and control means for provision of required pressure of gases analyzed.

6.1.3. A possibility to re-warm mass spectrometer components and units contacting gases being analyzed, up to 85-90 °C temperature, should be provided.

6.1.4. The mass spectrometer should be provided with its individual vacuum outpumping means.

6.1.5. The reference/calibration gases and gas mixtures for adjustment of the mass spectrometer should be supplied as a complete set of instrument kit.

6.2. Major Technical Characteristics of the Mass Spectrometer

6.2.1.The mass spectrometer is intended for implementation of quantitative analysis for gas admixtures content in working fluid of a cryocooler and the HCS as a whole.

A preliminary list of admixtures subjected to analysis is the following:

- water vapors;
- carbonic gas;
- carbon oxide;
- nitrogen;
- methane and other hydrocarbons;
- argon.

Pressure of analyzed gas mixtures at inlet to in-leaker adjustment valve of the MS makes up to $(0.1\text{-}1)*10^5$ Pa.

6.2.2. Range of atomic mass being analysed: 1…200 a.e.m.

6.2.3. Errors at identification of gas admixtures listed in para 6.2.1 should not exceed the following values:
- maximum 1 ppm at admixture concentration up to 20 ppm;
- maximum 3% at admixture concentration over 20 ppm.

6.2.4. Maximum time of one gas- sample analysis by means of MS should not exceed 60 sec.

6.3. Electric Power Supply, Monitoring and Control of Mass Spectrometer

Electric power supply, monitoring and control of Mass Spectrometer are provided autonomously and in accordance with relevant operational documentation.

6.4. Processing and Analysis of Measurement Results

Processing, analysis, archive storage and preparation of deliverables should be done by means of technical facilities included in MS complete set kit.

6.5. Mass Spectrometer Type Recommended

It is assumed that a quadruple, Stanford Research System CIS 200-type mass spectrometer may be admitted to be employed with Helium Complex Stand.

7. Admixture Gases and Water for Cryocooler Tests to Stability against Cryo-Deposit Pollutants

7.1.The preliminarily determined list of admixture gases and working substances assumed to be acquisited by US-party for implementation of tests (to stability of cryocoolers against cryo-deposit pollutants in working fluid) is as following:
- water;
- carbonic gas;
- carbon oxide;
- nitrogen;
- methane;
- argon.

NOTE: content and amount of outgassing products capable of building cryodeposits inside the cryocooler cold zone, will be periodically specified in the course of the HCS performance thtough the year.

7.5. The admixture gases employed at stand test should be used either in pure substance, or being diluted in helium within 1:10 to 1: 100 ratio. More precisely determined version of admixture percentage content should be specified in subsequent order in dependence on given test results (see note to para.7.1).

7.6. Amount of add pollutants within pure or diluted admixture gases should not exceed 0.1% of volume hereof.

7.7. Prior to beginning of the test, pure or diluted admixture gases should be filled under up to 2.0- 0.05 Mpa pressure into either of eight (10 liter-volume) GS1...GS8 gas bottles of A5 unit.

Gas bottle filling is generally recommended to be done by a specialized Gas Product Manufacturer, apart from the HCS area. The structural design of gas-bottle and HCS-interface facilities is represented by Fig. 2.9a.

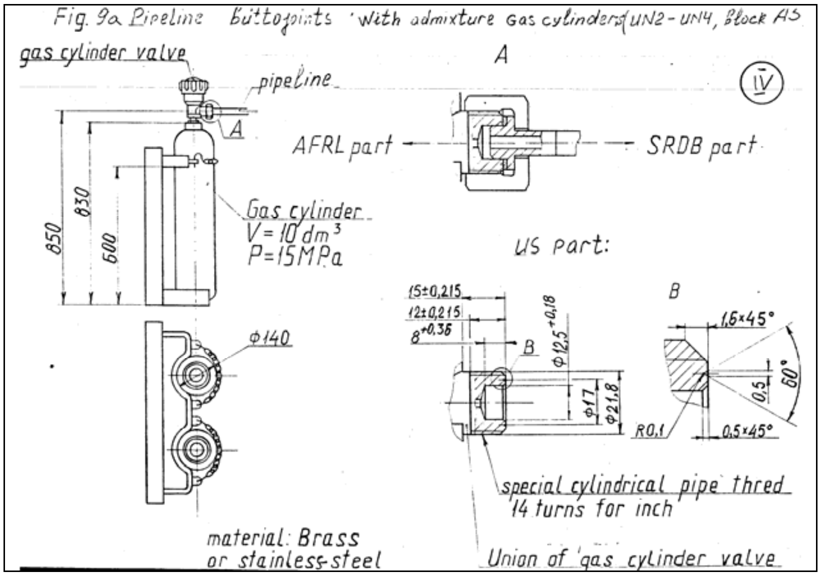

Fig.2.9a. Pipeline buttjoints with admixture gas cylinders (UN2- UN4 of block A5)

When necessary, GS1...GS8 gas bottles may be refilled from transport- purpose gas bottles right in HCS area via either of interfacing device UN2...UN4 of A5 unit. (the structural design of gas-bottle and HCS- interface facilities is represented by Fig.2.9a).

7.8. Filling the A7 vapor generator unit (see item A7 in Fig.2.1) should be done with application of double-stillage distilled water. The structural design of A7- unit water-filling throat is represented by Fig.2.9b.

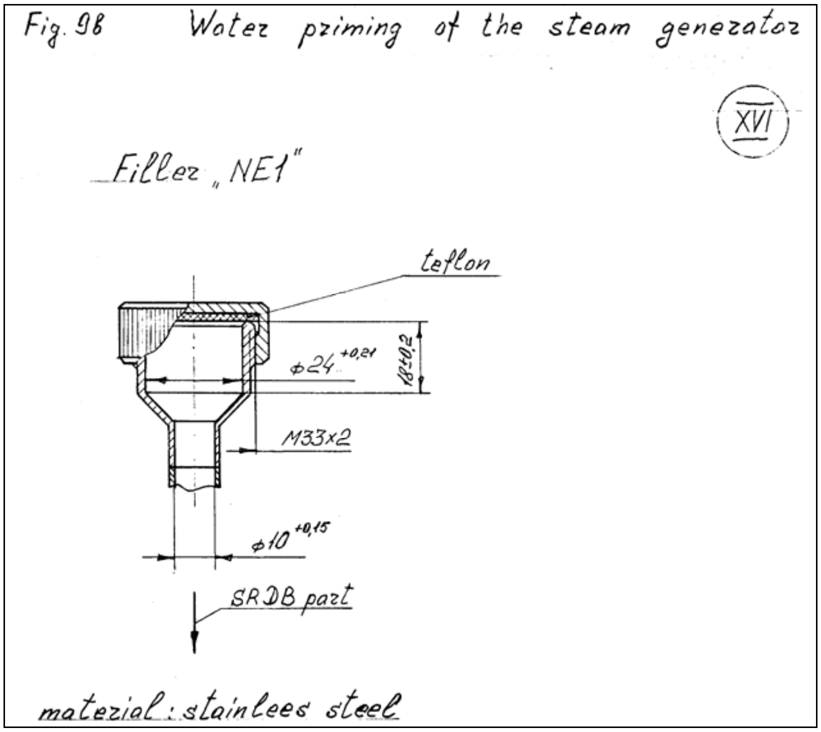

Fig.2.9b. Water priming of the steam generator

8. Filling the CAU- Traps with Liquid Nitrogen

8.1. Filling Facility Design

Structural design of filling facilities for A1 and A6- unit cryogenic traps, and of retractable LN-funnel and tankard are represented by Fig.2.10.

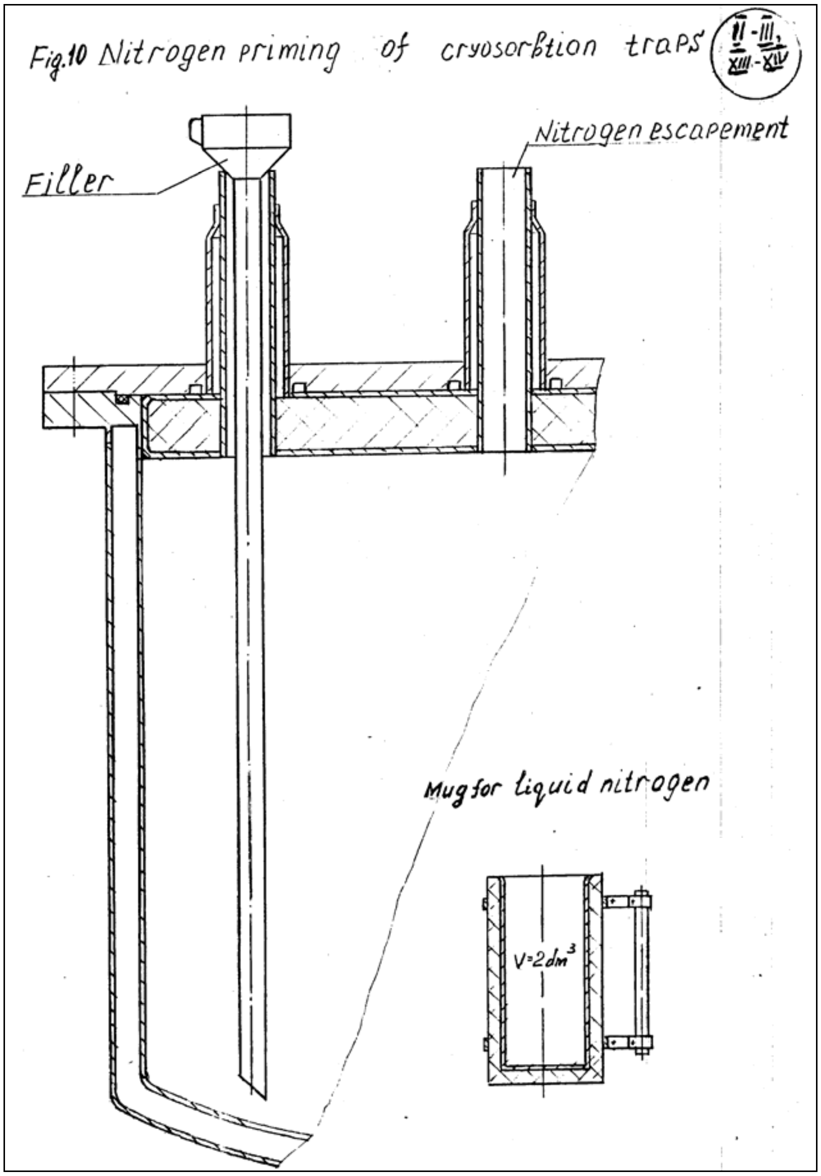

Fig. 2.10. Nitrogen priming of cryosorption traps

8.2. Requirements to LN Amount

Implementing a single cycle of cryocooler accelerated test, including:
- scavenging the sealing systems of CS1 and CH1 cryocoolers;
- filling the CS1 and CH1 cryocoolers and
- analysis of cryodeposit pollutants inside the CS1 cryocooler,

requires a preliminarily estimated amount of liquid nitrogen not in excess of 100 liter.

More precisely, this requirement should be specified upon development of designer's documentation to CAU-traps of A1 and A6 units, and upon identification of scavenging regimes for compressor sealing systems.

9. HCS- Control Computer Provision and Relevant Electronic Standard Hardware

9.1. It is assumed that equipment of the HCS facilities and hardware should be complemented by two PC kits:

a) to provide monitoring and control of the HCS facilities;
b) to process manual and automatic measurement files, to prepare resultant records and to carry out administrative management.

9.2. Technical requirements to computers, peripheral configuration and software hereto should be specified in course of further stages of HCS development.

10. Requirements to Premises for HCS Systems Dislocation

10.1. HCS-Premise Area

The premise area to lodge HCS equipment and facilities should be measured as minimum 15 meter long and minimum 10 meter wide.

10.2. HCS-Premise Climate

The HCS-premise should be provided with comfortable climatic conditions for personnel staff, like:
- 20-25^{o}C ambient room air temperature;
- 70-80 % humidity;
- maximum 60 Db odd noise level.

10.3. Ventilation

The HCS-premise should be provided with inlet/ outlet ventilation means, with minimum 5 times an hour air exchange.

10.4. Helium Evacuation from HCS-Premise

The HCS-premise should be equipped with gaseous- helium evacuation system to be used at:
- scavenging the cryocoolers' gap- sealing systems;
- evacuation of working fluid from cryocoolers;
- other technological operations.

Pressure drop in drainage system (between atmospheric level and HCS outlet) should not exceed 5 mm Hg. Helium consumption at above operations makes up to 5 m^3 an hour, whereby total amount of helium being aborted in a single test cycle accomplished makes up maximum 10 m^3 .

The problem of possibility to abort helium directly into HCS- premise atmosphere should be contemplated.

Fig.2.11 represents a structural design of HCS connection joints to drainage system.

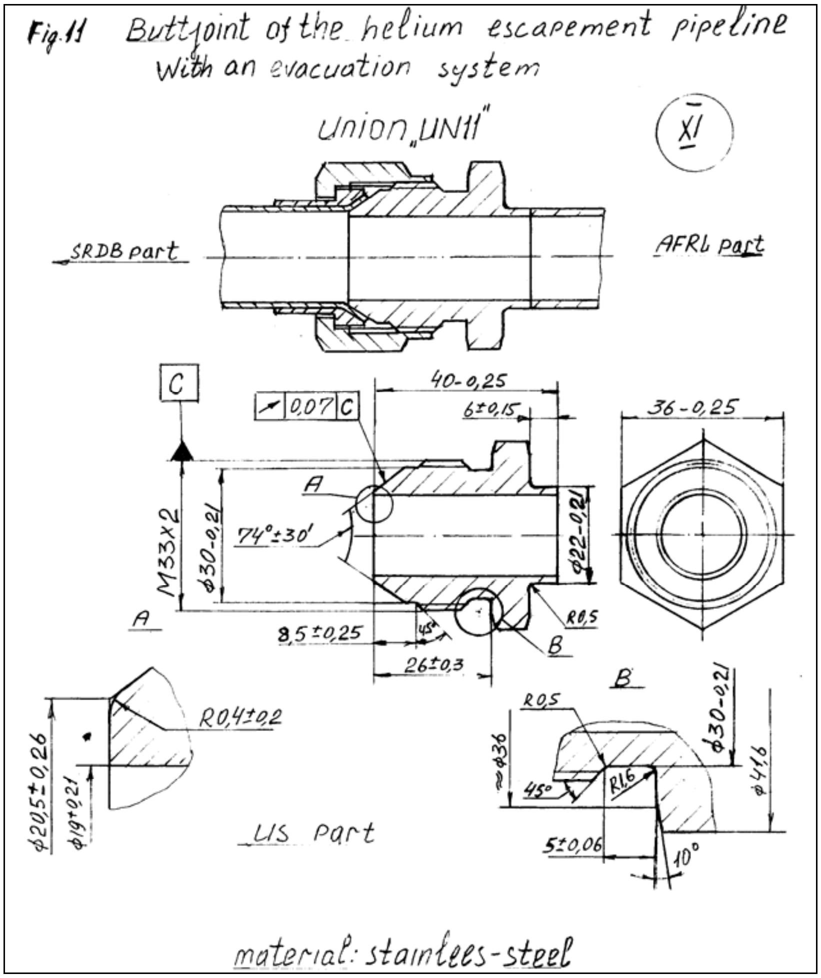

Fig.2.11. Buttjoint of the helium escapement pipeline with an evacuation system

10.5.Electric Power Supply

The HCS premise should be equipped with electric power supply system made in compliance with normal safety provisions accepted in USA.

Technical requirements to electric power supply of the HCS (including connecting joints structure design) should be verbalized upon development of designer’s documentation and coordinated resolution as to application of US-made products in compliance with present Document.

10.6. Auxiliary Equipment

10.6.1.The roadways to, and door dimensions of HCS premise should comply with transport conditions in delivery of big- bulk cargoes (such as thermo-control chambers, outpumping units, mass spectrometer units etc).

Mass & dimensional characteristics of the HCS equipment should be specified upon development of designer’s documentation and coordinated resolution as to application of US-made products in compliance with present Document.

10.6.2. Content and characteristics of the HCS auxiliary systems (such as water supply, lighting, LN delivery and storage etc) should be specified in course of further stages of HCS development.

3. RESULTS OF STAND MOCK-UP MODEL EXPERIMENTS

3.1. Stand Mock-Up Experiments for Accelerated Tests of Compressor Body Gas- Tightness under Thermo- Cycling

3.1.1. Purpose of Experiments

Purpose of experiments (carried out on stand mock-up for accelerated thermo-cycling tests of compressor body gas- tightness) is an optimization of heating and cooling regimes in accelerated cycle with a full- scale compressor body mock-up.

Optimization of thermo-cycling regimes implies a choice of methods of cooling (as type of a cryoagent and temperature hereof) and heating (as means of heating, ambient temperatures) at simultaneous monitoring of mechanical stressed state of compressor body (including a gas-static component of stresses, and- a cyclic component of thermal stresses). A major requirement to accelerated thermo-cycling tests regime is reservation of the compressor body stressed state level within limitation constraints to body- material fatigue limit on basis of 5.10^6 cycles (see Final Report to #7 Contract of Oct 1999, part.3.3).

3.1.2. Contents of Experiments

As cooling media, there have been selected ethyl alcohol being cooled down to –76^{o}C, and liquid nitrogen (LN_2). Both these substances ensured us an optimization of different cooling methods with purpose to ultimately identify an appropriate medium of a coolant.

The following measures have been provided:

1. Implementation of compressor body mock-up heating and cooling cycles within standard time interval (90 minutes a cycle) over +20 to +70^{o}C $\Rightarrow$ +70 to –70^{o}C $\Rightarrow$ –70 to +20^{o}C temperature regimes.
2. There has been obtained a calibration curve for deformation and stress inside the compressor body, depending on interior pressure value.
3. There have been measured temperature gradients that occur inside the body of compressor heated up to +70^{o}C, during its cool-down inside the LN_2 and at cooling down to –70^{o}C (inside cooled- alcohol medium), along with definition of time intervals required for cooling.
4. There have been determined: a) LN_2 consumption volume rates at different variants of mock-up body cooling from +70^{o}C
   and b) cold alcohol temperature rise at cooling the mock -up down to –70^{o}C.
5. There have been defined: a) gradient of temperatures at re-heating the mock-up body and b) from the +20 up to +70^{o}C heating time interval at placing the mock-up body into furnace heated up to 200^{o}C.

3.1.3. Results of Experiments

1. With 90- min heating cycle, temperature gradient between outer and inner body- walls does not exceed 1^{o}C.

2. Tangental stress measured within a body-wall at 15 at interior pressure, makes up ~2,5 кg/mm^2 .
3. While cooling the compressor body inside LN_2 medium from +70^{o}C down to -70^{o}C, maximum temperature gradient ΔT_{max} across 3mm- thick body wall amounts to ~55 ^{o}C, whereby time required to provide such cooling takes about 1 min.
   While cooling inside the -72^{o}C alcohol medium (under similar conditions), temperature gradient ΔT_{max} makes up ~19 ^{o}C, whereas cooling time takes about 3.5 to 4 min.
4. At cooling the 1.7-kg body mock-up inside LN_2 medium within +70 to -70^{o}C temperature range, LN_2 consumption makes up about 1 liter per cycle.
   When cooling the body mock-up inside 7 liter alcohol medium, alcohol temperature goes up by about 5 ^{o}C.
5. Compressor body heating up to +70^{o}C in a furnace of about 200^{o}C temperature takes about 10 min time at maximum gradient ΔT_{max} ~3^o C over wall- thickness.

Thus, preliminary experiments accomplished have shown that LN_2 fails to be chosen as a cryoagent (from viewpoint of thermo- mechanical stresses level), due to hazardous temperature gradient over body- wall thickness. As a cryoagent, ethyl spirit (the alcohol) being cooled down to –75^{o}C meets all requirements to accelerated thermo-cycling methodology. It is assumed that, in order to shorten the heating half- cycle time down, it's necessary to somewhat elevate the furnace temperature with provision of safe temperature gradient ΔT_{max} value.

Currently, optimization efforts for accelerated thermo- cycling regimes and for selection of hazard- free stress state in a body material are carried on.

3.2 Computed estimations for different methods of cryoagent cooling for thermocycling stand facility

As a cryoagent, ethyl alcohol has been selected due to its low freezing temperature, substantially high specific thermal capacity and ecologic purity. The alcohol in amount of about 60 liter should be filled inside cooling chamber of the thermo- cycling stand.

Three cooling variants were considered for cooling the alcohol down to –70^{o}C operational temperature and to maintenance of said temperature: with application of LN_2, with usage of solidified carbonic acid, and by means of a cooling machine.

Computations are based on the following initial data:

- compressor weight: 3.2 kg;
- compressor body material aluminum alloy;
- thermocycling temperature interval: +75 ÷ -75^{o}C;
- duration of a heating/ cooling half- cycle: every 4 min.

Thermal computations show that in case if alcohol is cooled down in a heat exchanger being lodged inside a liquid nitrogen- filled Dewar vessel, the liquid nitrogen consumption will amount to 400 liter a day.

Cooling the alcohol and maintenance of its temperature on a pre- determined level by means of direct loading of solidified carbonic-acid into cooling chamber has its disadvantages in low cooling efficiency hereof, and in requirement for daily consumption of solid carbonic-acid in amount of 150 kg (i.e., 0,1 m ^{3}).The most effective solution is assumed to be an application of active cooling system by means of a cooling machine. Maintenance of required alcohol temperature inside the cooling chamber is carried out by means of alcohol pump-through a heat exchanger being lodged inside a cooling machine. Thermal computations show that in order to implement such a variant of cryoagent temperature maintenance, its necessary to employ a cooling machine of minimum 1000 kcal/hr cooling efficiency, along with minimum provided temperature not above than -100^{o}C.

3.3 Experiments for high- frequency fatigue tests mock-up of pilot prototypes of compressor linear drive piston- mount flexible springs

3.3.1 Purpose of Experiments

Purposes of experiments are:

1. Practical optimization of high- frequency fatigue tests methodology for pilot prototypes of compressor linear drive suspension springs.
2. Experimental investigation of a linear drive suspension spring mechanical behavior at changing the loading frequency Δf within 40 $\div$ 400 Hz interval.
3. Obtaining of amplitude and frequency characteristics of a linear drive suspension spring being investigated.
4. Study of behavior peculiarities for mount- spring constituent portions
5. Correction of frequencies suitable for accelerated tests.

3.3.2 Results of Experiments

Experimental work activities on cyclic loading of cryocooler compressor piston- mount flexible spring members have been carried out.

Said flexible spring members are fabricated as flat discs provided with three punched- out cuts (that correspond with their shape to Archimedes's spiral geometry) thus forming three spiral narrow "petals" of the spring disc (like so-named Oxford flexure bearings).

Said spring is flanged up around its periphery, and its center portion is coupled with a reciprocating rod of the drive unit. A linear drive is used as a test drive unit being able to reciprocate center portion of tested springs with up to $\pm$4 mm amplitude. Auto-oscillations frequency f_{dr} of the drive makes up 22 Hz, which is left outside the required (f_1=40 to f_{max}=400 Hz) accelerated- tests frequency- range, and hence, does not influence measurements accuracy.

Experimental check has shown that resonance frequency f_1 of our drive-and- spring unit tested made up 37,5 Hz, where required reciprocation amplitude was provided by means of **P** $\leq$ 5 **BA** power applied to the drive unit. Similar reciprocations at elevated frequencies (being forced oscillations) require considerably greater power rates.

We can reduce required power value by arranging mechanical resonance for "drive - tested spring" system at required frequency. Resonance frequency can be altered by changing spring rigidity whereby, following mechanical laws, auto- frequency of spring system,**f**, is described by 1/2πvk/m, where k - spring rigidity, and m - an oscillating mass. Thus, furnishing the drive unit with additional elastic members of different rigidity, we can alter (and, hence, increase) resonance frequencies at practically the same amount of power supply to the drive unit. In this experiment, the drive unit has been equipped with an additional elastic resilient member as a flat metallic plate fixed from one end to the drive unit body, and another end portion was connected to the drive's reciprocating rod. A required frequency has been selected by a choice from a series of such plates of appropriate thickness.

Just the very first experiments have revealed an occurrence of individual mechanical flutter in spiral petals of springs under tests at elevated frequencies. Said flutter occurs as independent oscillations of spring member portions along spiral chord of spring petals.

It's evident that elevated operational frequencies applied at accelerated tests should be optioned so as to exclude an occurrence of above- mentioned individual flutter. Such a requirement demanded to formulate a methodology of definition of individual resonance frequencies.

Said methodology is based on definition of frequencies that correspond to minimum power (for current) supply. The motion inside a tested item appears as forced oscillations; and mechanics law have it that oscillations amplitude is proportional to $1/(1-\omega^2/\rho^2)$ formula, where ω- exterior effect frequency and ρ- frequency of auto-oscillations.

It is obviously necessary (judging from the formula) to increase amplitude at pre- determined power of exterior effect (or, just the same, to reduce this power at pre- determined amplitude of oscillations) in order to approximate the ω^2/ρ^2 member as much close to 1- factor. In other words, it's critical to perform at frequencies approximated to harmonic auto- oscillation frequencies -ρ.

Experimental check has proven a viability of the methodology. Thus, Fig.3.1 represents a dependence of current supplied to the drive on power- supply frequency under following conditions:

a) without additional elastic members (being flat plates, curve 1);
b) with an additional elastic flat plate member, curve 2;
c) with two members, curve 3;
d) with four members, curve 4.

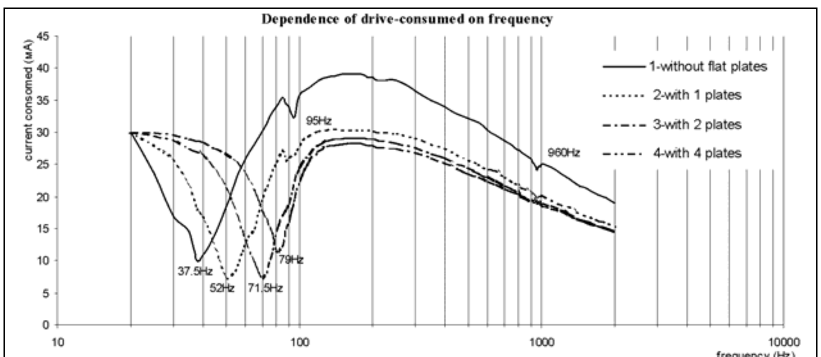

Fig.3_1.pcx

Fig.3.1 Dependence of current consumed by the drive unit, on power supply frequency.

No.1 curve distinctly shows current minimums upon main resonance frequency of the system, $f r_1$=37.5 Hz, as well as minimums upon individual flutter resonance frequencies $f r_2$=95 Hz and $f r_3$=960 Hz.

The diagram also shows a similar dependence at introduction of one, two or four additional elastic (flat plate) members assembled in a package. There is a clear view of changed (by increase) frequency of main resonance with introduction of ever more elastic members.

Individual flutter discovered in test experiments for definite parts of suspension springs is a hazardous phenomenon capable of bringing a premature destruction of springs.

In order to evade us against occurrency of flutter at accelerated high- frequency fatigue tests of compressor linear drive, the relevant test stand should be equipped with a special (electronic) unit intended for discovery of flutter- oscillation frequencies in springs tested, with purpose of avoiding these damage frequencies.

It’s also noteworthy that with introduction of additional elastic members, there is only major linear drive- spring tested - system resonance frequency that is subjected to change, whereas individual flutter frequencies of tested spring members remain practically the same.

4. INITIAL DATA FOR IDENTIFICATION OF US- MADE COMPLETE SET EQUIPMENT AND FACILITIES FOR COMPRESSOR BODY THERMOCYCLING TEST STAND

Every thermal cycle includes two half-cycles: heating up +75^{o}C and cooling down -70^{o}C. For this reason, the compressor unit under test should be automatically and periodically repositioned in- between heating and cooling chambers by the program controller:

1. Compressor body should be heated by a series of 250W infra- red glow lamps. Computed estimations show that required total lamp power should amount to 2.5kW.

We consider it expedient that test stand set should be completed with said lamps of US make. For documentation provisions, we need knowing overall dimension and fixture- fitting lamp parameters.

2. The test- stand cooling system should be completed with a US- made cooling machine of minimum 1000 kcal/hr cooling efficiency, along with minimum provided temperature not above than -100^{o}C.

3. Compressor body gas- tightness after multiple effect of thermal cycles should be monitored by means of helium leakage detector. Therefore, the test stand should be equipped with standard helium leakage detector manufactured in the United States of America.

5. COMPRESSOR LINEAR DRIVE HIGH FREQUENCY ACCELERATED FATIGUE TEST STAND (INITIAL DATA FOR IDENTIFICATION OF APPROPRIATE US-MADE COMPLETE SET EQUIPMENT

Fig. 5.1 represents a block diagram of the stand. High- frequency unit is an apparatus being engineered and supplied by Ukraine- party.

All other units represented by Fig.5.1 are standard products to be supplied for AFRL- held tests by US- party.

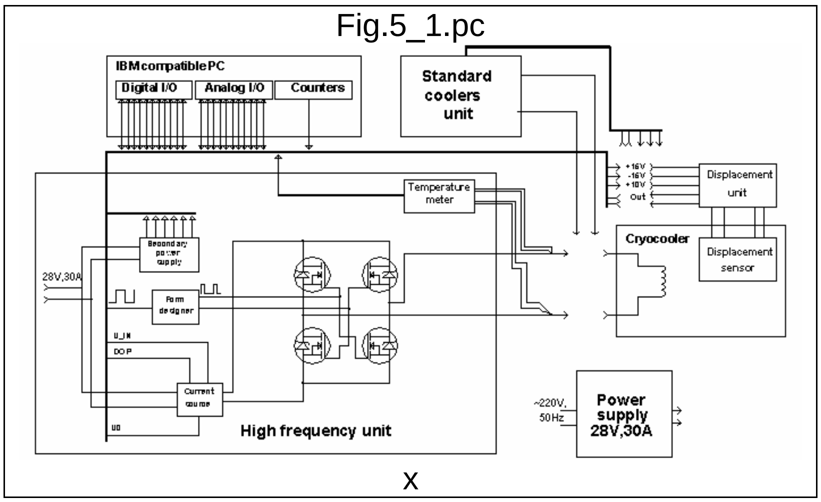

Fig.5.1. Block diagram of linear drive high frequency accelerated fatigue test stand

Here are the following technical requirements to the equipment:

Name&Designation/ Function	Characteristics	Notes
1. D.C. Power supply unit output peak voltage, V max. Load peak current, A max pulsation voltage, V	 28±10%; 30 1	
2. Personal Computer	not worse than: f=200 MHz; HDD = 6.4 Gb; RAM 32 Mb; 1 ISA slot.	IBM- system compatible PC
3. Axial position sensor with secondary apparatus means: - power voltage, V: - sensitivity, V/mm: - measured reciprocation range, mm: - operational frequency range, Hz:	 +15,-15,+10; 1 minimum ±5; 40 -- 300	
4. Drive unit power supply connector: voltage, V: current, A:	 Minimum 28; minim 30	